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Technical Memorandum

# BOTTOM CHARACTERISTICS AND SHALLOW WATER SOUND PROPAGATION: AN ACOUSTICIAN'S VIEW AT MID-FREQUENCIES (500 - 5000 HZ)

Date: 21 September 1993

Prepared by: Joseph M. Monti
Joseph M. Monti
Surface ASW Systems Department

David Browning
David G. Browning
Environmental and Tactical Support Systems Department

Peter D. Herstein
Peter D. Herstein
Surface ASW Systems Department

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14. ABSTRACT
**Interaction with the bottom can certainly be a dominant factor in shallow water sound propagation, hence there is a renewed interest in understanding bottom characteristics. A study of 10 typical shallow water sites indicates the extent of this problem, at least from an acoustician's perspective. Perhaps surprisingly, strong bottom interaction due to a totally downward refracting sound speed profile occurred only 25% of the time, with some form of ducting occurring the remaining time. Eight of the locations had a "hard" or "fast" bottom which results in a step-like bottom loss, with the increase occurring at the critical angle. It was typically found, under downward refracting conditions, that sources and receivers located near the bottom would have dominant propagation paths with less-than-critical-angle bottom interactions and hence, relatively low propagation loss. Sources near the surface, on the other hand, may have steeper angle interactions, higher bottom loss, and correspondingly higher propagation loss. Therefore, the sound speed profile, source/receiver location, water depth, and propagation range must all be considered to anticipate the extent of the bottom interaction.**

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**shallow water sound propagation; bottom characteristics; bottom interaction; sound speed profile**

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## ABSTRACT

Interaction with the bottom can certainly be a dominant factor in shallow water sound propagation, hence there is a renewed interest in understanding bottom characteristics. A study of 10 typical shallow water sites indicates the extent of this problem, at least from an acoustician's perspective. Perhaps surprisingly, strong bottom interaction due to a totally downward refracting sound speed profile occurred only 25% of the time, with some form of ducting occurring the remaining time. Eight of the locations had a "hard" or "fast" bottom which results in a step-like bottom loss, with the increase occurring at the critical angle. It was typically found , under downward refracting conditions, that sources and receivers located near the bottom would have dominant propagation paths with less-than-critical-angle bottom interactions and hence, relatively low propagation loss. Sources near the surface, on the other hand, may have steeper angle interactions, higher bottom loss, and correspondingly higher propagation loss. Therefore, the sound speed profile, source/receiver location, water depth, and propagation range must all be considered to anticipate the extent of the bottom interaction.


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The authors of this memorandum are located at the Naval Undersea Warfare Center Detachment, New London, Connecticut 06320.

**BOTTOM CHARACTERISTICS AND SHALLOW WATER SOUND PROPAGATION: AN ACOUSTICIAN'S VIEW AT MID-FREQUENCIES (500 - 5000 HZ)**

## INTRODUCTION

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# BOTTOM CHARACTERISTICS AND SHALLOW WATER SOUND PROPAGATION: AN ACOUSTICIAN'S VIEW AT MID-FREQUENCIES (500 - 5000 Hz)


JOSEPH M. MONTI
DAVID G. BROWNING
PETER D. HERSTEIN

NAVAL UNDERSEA WARFARE CENTER DIVISION NEWPORT
NEW LONDON DETACHMENT
NEW LONDON, CT 06320



1992 AGU FALL MEETING
7 - 11 DECEMBER 1992
SAN FRANCISCO, CA


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# ABSTRACT

INTERACTION WITH THE BOTTOM CAN CERTAINLY BE A DOMINANT FACTOR IN SHALLOW WATER SOUND PROPAGATION HENCE THERE IS A RENEWED INTEREST IN UNDERSTANDING BOTTOM CHARACTERISTICS. A STUDY OF 10 TYPICAL SHALLOW WATER SITES INDICATES THE EXTENT OF THIS PROBLEM, AT LEAST FROM AN ACOUSTICIAN'S PERSPECTIVE. PERHAPS SURPRISINGLY, STRONG BOTTOM INTERACTION DUE TO A TOTALLY DOWNWARD REFRACTING SOUND SPEED PROFILE OCCURRED ONLY 25% OF THE TIME, WITH SOME FORM OF DUCTING OCCURRING THE REMAINING TIME. EIGHT OF THE LOCATIONS HAD A "HARD" OR "FAST" BOTTOM WHICH RESULTS IN A STEP-LIKE BOTTOM LOSS, WITH THE INCREASE OCCURRING AT THE CRITICAL ANGLE. IT WAS TYPICALLY FOUND, UNDER DOWNWARD REFRACTING CONDITIONS, THAT SOURCES AND RECEIVERS LOCATED NEAR THE BOTTOM WOULD HAVE DOMINANT PROPAGATION PATHS WITH LESS-THAN-CRITICAL-ANGLE BOTTOM INTERACTIONS AND HENCE RELATIVELY LOW PROPAGATION LOSS. SOURCES NEAR THE SURFACE, ON THE OTHER HAND, MAY HAVE STEEPER ANGLE INTERACTIONS, HIGHER BOTTOM LOSS, AND CORRESPONDINGLY HIGHER PROPAGATION LOSS. THEREFORE, THE SOUND SPEED PROFILE, SOURCE/RECEIVER LOCATION, WATER DEPTH, AND PROPAGATION RANGE MUST ALL BE CONSIDERED TO ANTICIPATE THE EXTENT OF THE BOTTOM INTERACTION.

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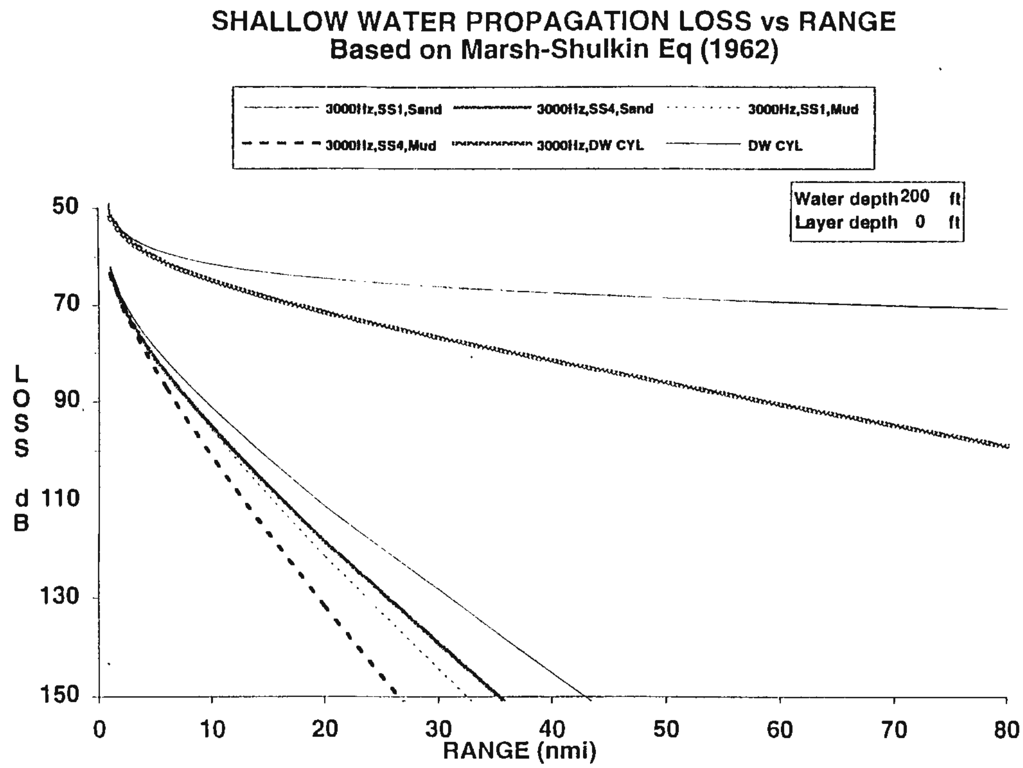


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# OUTLINE

**KEY QUESTION: BY OPTIMUM DEPTH PLACEMENT OF A RECEIVER CAN WE MINIMIZE PROPAGATION LOSS FROM A GIVEN SOURCE DEPTH IN SHALLOW WATER?**

1. IMPACT OF BOTTOM LOSS IN SHALLOW WATER
2. GRAZING ANGLE DEPENDENCE AND SOURCE/RECEIVER DEPTH
3. WORLDWIDE SURVEY
4. RESULTS AND CONCLUSIONS

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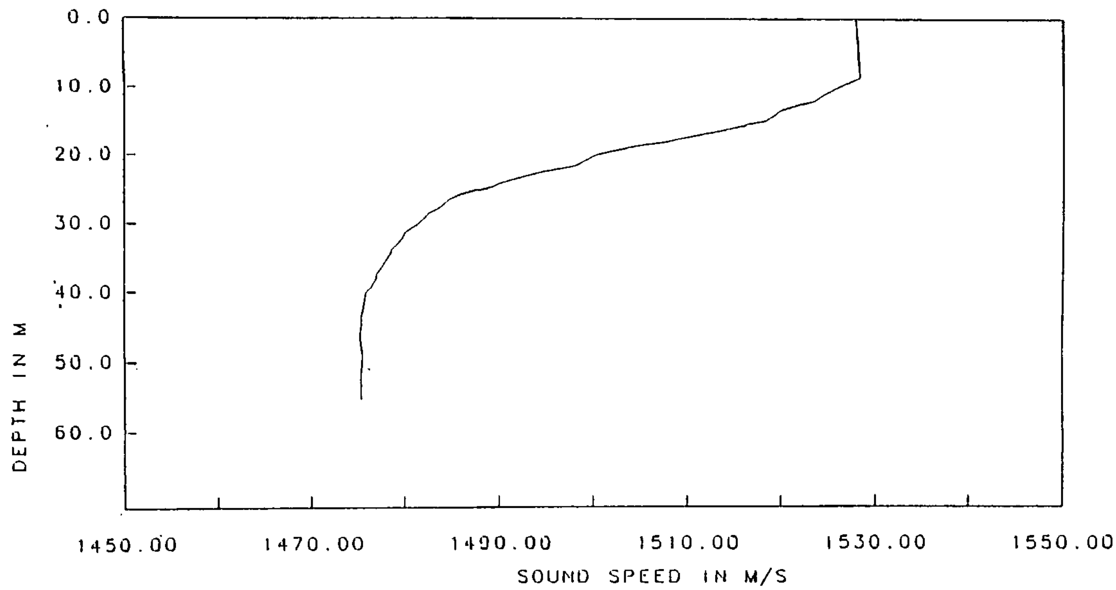
## SHALLOW WATER SOUND SPEED PROFILE
## (SOUTH OF LONG ISLAND, MAY)

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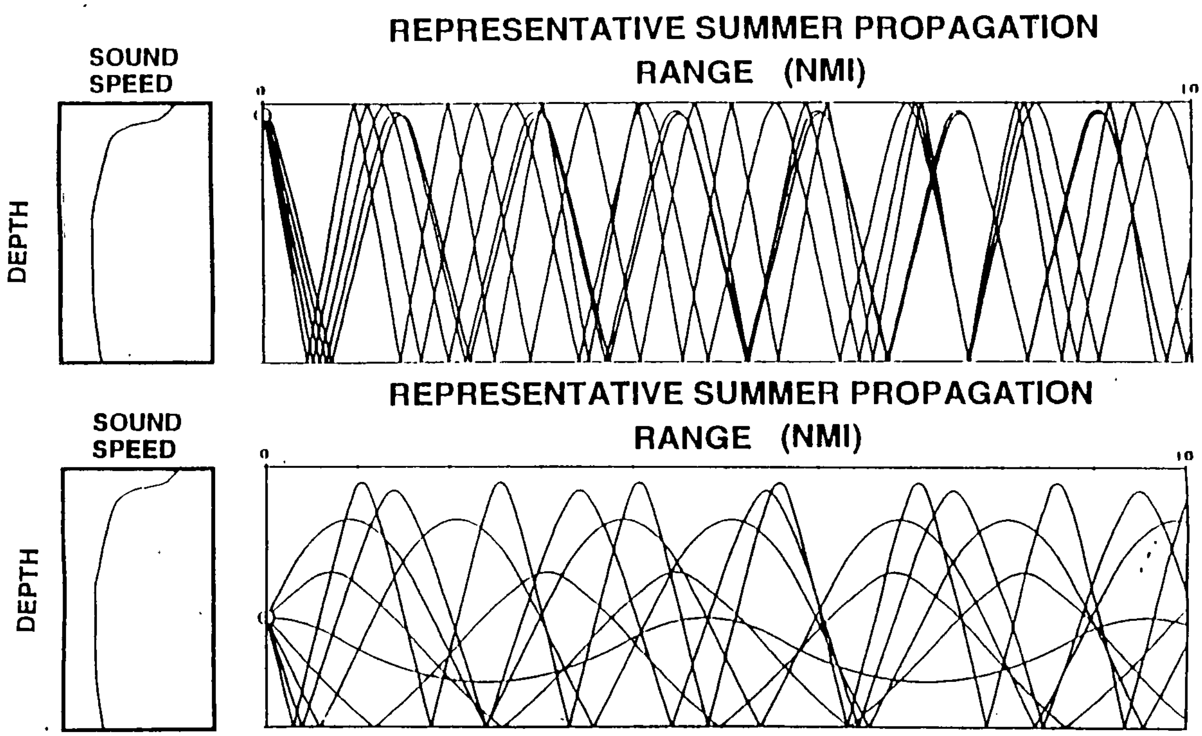
# SHALLOW WATER

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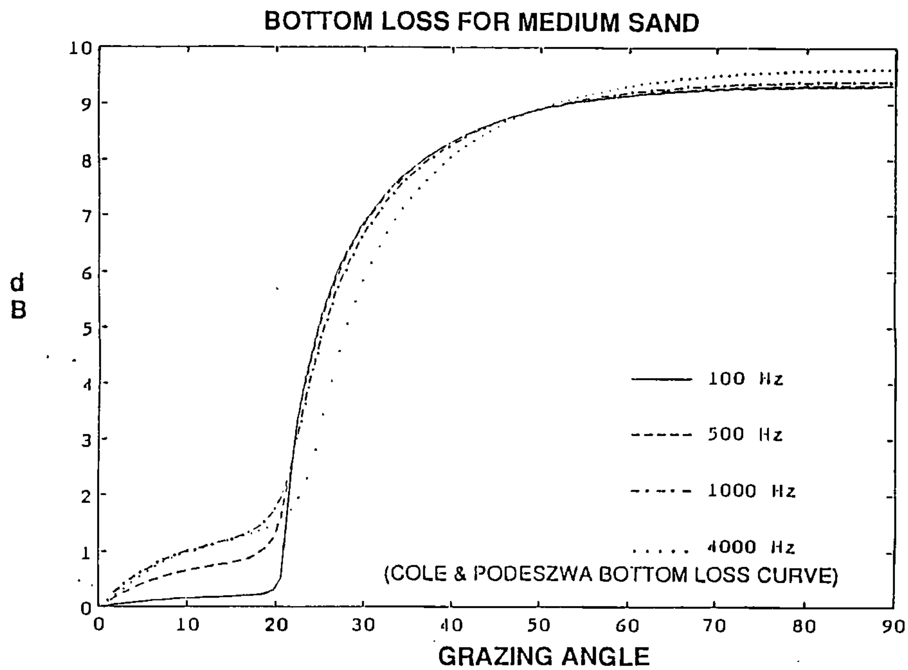
# BIOT THEORY

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IT IS MEANINGFUL TO COMPARE THIS LOSS TO BOTTOM LOSS ENCOUNTERED IN SHALLOW WATER (AREA FOXTROT, SOUTH OF LONG ISLAND, EXPERIMENTAL DATA RECENTLY OBTAINED BY J.M. TATTERSALL, NUWCDIVNPT.) UNDER SUMMER DOWNWARD REFRACTING CONDITIONS FOR A 15 DEGREE GRAZING ANGLE (CORRESPONDS TO RAYPATH FROM A HULL MOUNTED SURFACE SHIP SONAR - SKIP DISTANCE .65 KM), AND A 5 DEGREE GRAZING ANGLE (A TOWED ARRAY BELOW THE THERMOCLINE - SKIP DISTANCE .80 KM.)

RATE OF LOSS (ATTENUATION) COMPARISON, SHALLOW WATER NORTH ATLANTIC

| FREQ. | DEEP WATER (THORP) | SHALLOW WATER (LOV. C. 1.8) | BL RATE 15 DEG.. | BL RATE 5 DEG. |
|---|---|---|---|---|
| 100 HZ | .001 dB/KM | .0018 dB/KM | .32 dB/KM | .13 dB/KM |
| 1000 HZ | .062 | .106 | 1.84 | .75 |
| 3500 HZ | .220 | .326 | 1.84 | .75 |

LOSS COMPARISON AT 50 KM (ACTIVE, TWO-WAY, 100 KM TOTAL PATH) FOR PROPAGATION IN NORTH ATLANTIC SHALLOW WATER - SUMMER CONDITIONS

| FREQ. | DEEP WATER (THORP) | SHALLOW WATER (LOV. C. 1.8) | BOT. LOSS 5 DEG.. | BOT. LOSS 15 DEG. |
|---|---|---|---|---|
| 100 HZ | .1 dB | .18 dB | 13. dB | 32. dB |
| 1000 HZ | 6.2 | 10.6 | 75. | 184. |
| 3500 HZ | 22.0 | 32.6 | 75. | 184. |

LOSS COMPARISON AT 20 KM (ACTIVE, TWO-WAY, 40 KM TOTAL PATH) FOR PROPAGATION IN NORTH ATLANTIC SHALLOW WATER - SUMMER CONDITIONS

| FREQ. | DEEP WATER (THORP) | SHALLOW WATER (LOV. C. 1.8) | BOT. LOSS 5 DEG.. | BOT. LOSS 15 DEG. |
|---|---|---|---|---|
| 100 HZ | .04 | .072 | 5.2 | 12.8 |
| 1000 HZ | 2.48 | 4.24 | 30. | 73.6 |
| 3500 HZ | 8.8 | 13.0 | 30. | 73.6 |

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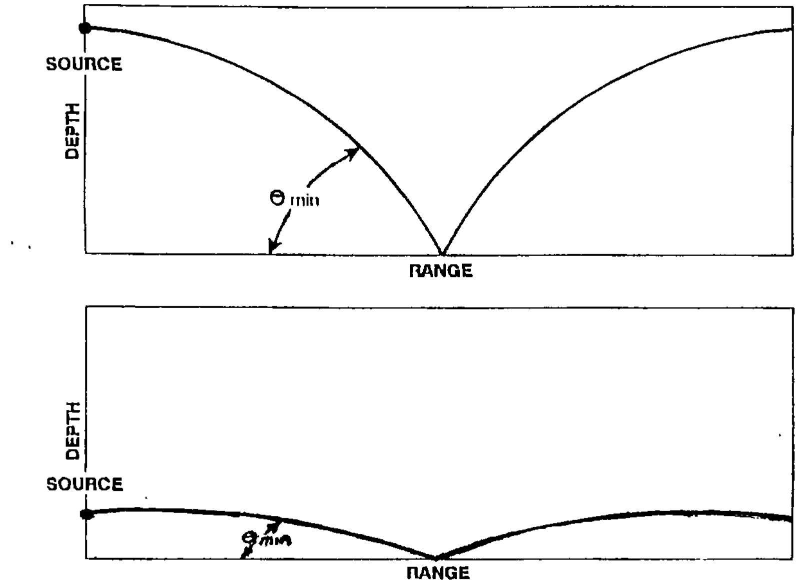
# THE MINIMUM OBTAINABLE BOTTOM GRAZING ANGLE IS A FUNCTION OF SOURCE DEPTH

$$\theta_{min} = \cos^{-1} \frac{C_{SOURCE}}{C_{BOUNDARY}}$$

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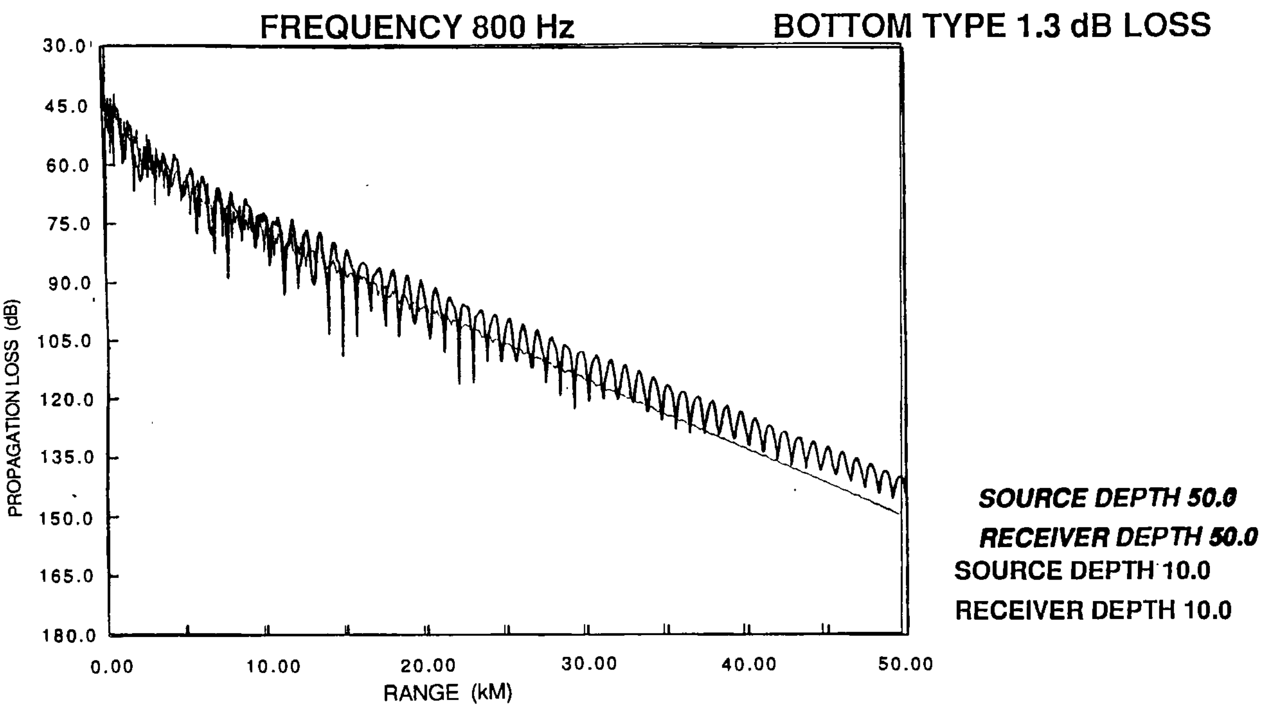
# SHALLOW WATER TRANSMISSION LOSS

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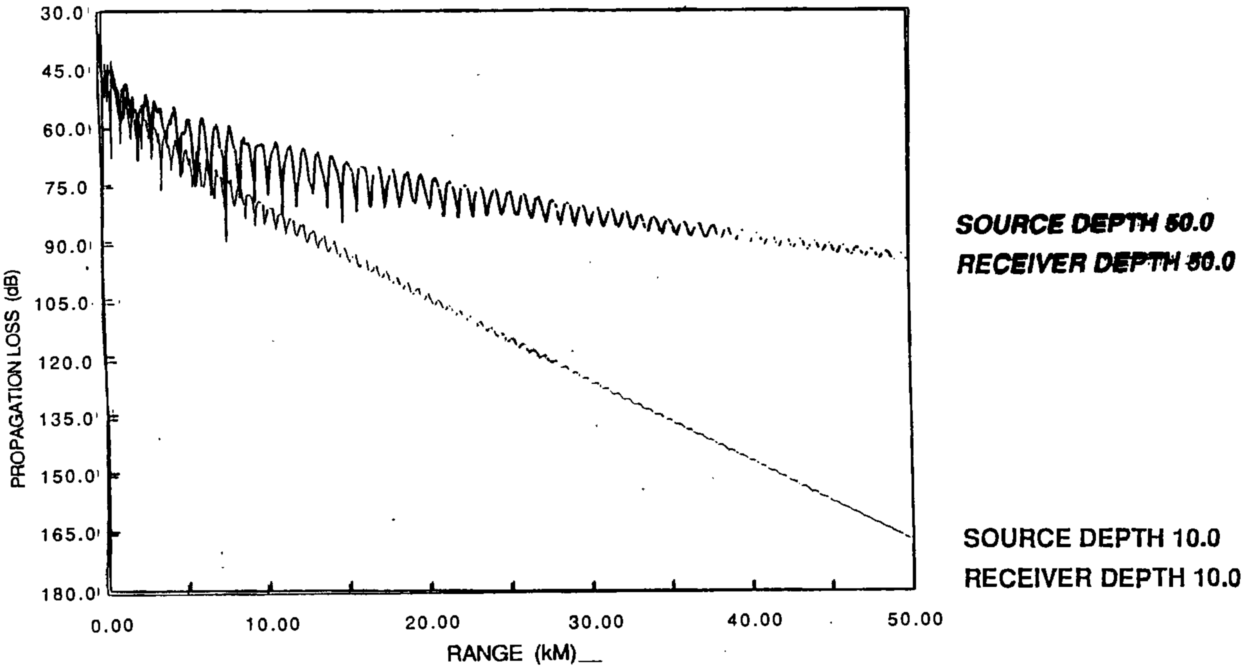
## SHALLOW WATER TRANSMISSION LOSS

FREQUENCY 800 Hz BOTTOM TYPE BIOT (SAND)

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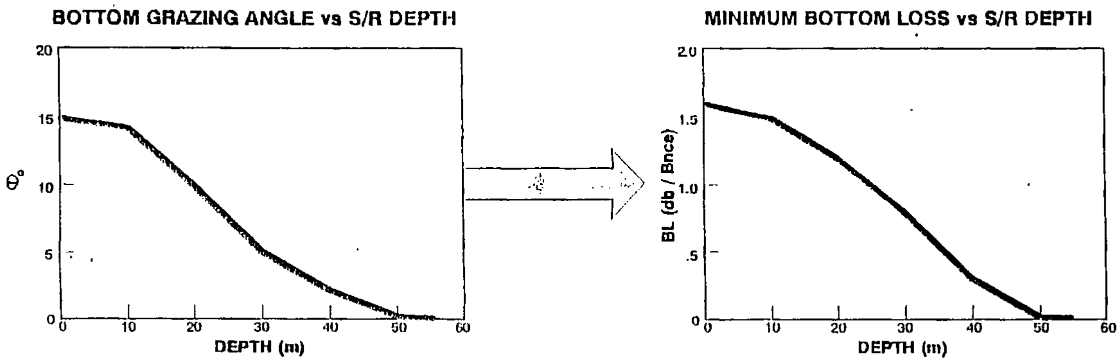
# PHENOMENOLOGICAL EXPLANATION OF DEPTH DEPENDENT TRANSMISSION LOSS




S/R DEPTH = min [SOURCE DEPTH, RECEIVER DEPTH]

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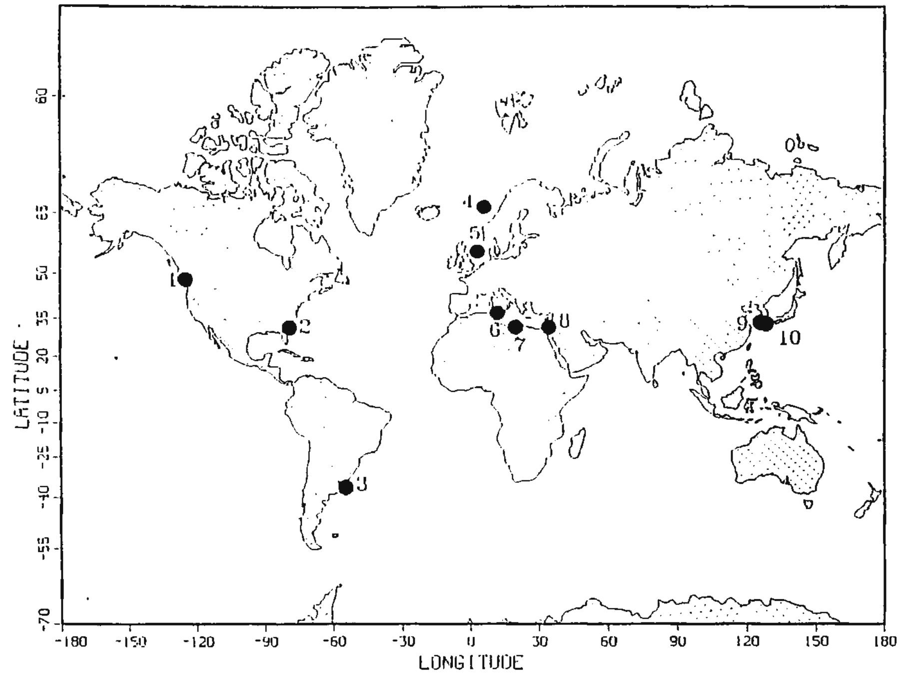
# SHALLOW WATER LOCATIONS

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# SOUND SPEED PROFILE ATTRIBUTES

| LOCATION | SOUND SPEED PROFILE CHARACTER | | | | WATER DEPTH |
|---|---|---|---|---|---|
| | WINTER [Feb] | SPRING [May] | SUMMER [Aug] | FALL [Nov] | |
| E. YELLOW SEA | D400' | C250' | D35',C150' | D165' | 400' |
| GULF OF SIDRA | D255' | DOWN REF | DOWN REF | D75' | 500' |
| NORWEGIAN SEA | D850' | D350' | D75' | D300' | 2000' |
| KINGS BAY | D90' | D40' | DOWN REF | D90' | 1250' |
| NORTH SEA | D300' | D80',C150' | C175' | D175', C250' | 300' |
| STRAITS OF SICILY | D600'/2000' | C350' | C450' | D100', C350' | 2000' |
| *MONTEVIDEO | DOWN REF | D100' | DOWN REF | DOWN REF | 300' |
| SINAI | D400'/660' | DOWN REF | DOWN REF | D125' | 660' |
| KOREAN STRAITS | D250' | D80' | D65' | D165' | 500' |
| JUAN DE FUCA | D80' | DOWN REF | DOWN REF | D55' | 600' |

Dn - Surface Duct, n ft thick

Cn - Sound Channel (Sound Velocity minimum) at n ft

DOWN REF - Downward Refracting Conditions over the entire water column

* Southern Hemisphere, therefore Seasons are reversed

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- PURELY DOWNWARD REFRACTION OCCURS IN 25% OF THE ENVIRONMENTS EXAMINED IN THIS SHALLOW WATER STUDY
- DOWNWARD REFRACTING CASES FOLLOW EXPECTED MONOTONIC DEPENDENCE ASSOCIATED WITH BOTTOM INTERACTION AND ATTENUATION
- 75% OF THE ENVIRONMENTS IN THIS STUDY HAVE SOME FORM OF ACOUSTIC DUCT OR NEAR SURFACE SOUND CHANNEL
- DUCTED PROPAGATION MAKES SOURCE/RECEIVER DEPTH CONFIGURATION MORE CRITICAL AND ALLOWS DUCT LEAKAGE AND/OR SURFACE LOSS TO BECOME ADDITIONAL SIGNIFICANT FACTORS
- CUTOFF FREQUENCIES FOR DUCTED PROPAGATION INTRODUCE A SIGNIFICANT FREQUENCY DEPENDENT COMPONENT TO SOURCE/RECEIVER OPTIMIZATION TO MINIMIZE TRANSMISSION LOSS

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# GRAZING (ARRIVAL) ANGLES OF DOMINANT EIGENRAYS

## SUMMER PROFILES - DOWN REFRACTING
## TARGET ON BOTTOM
## RANGE = 20 NMI

| LOCATION | SOURCE = 25 FT | SOURCE = "DEEP" |
|---|---|---|
| GULF OF SIDRA | 10 - 11° | 1 - 2° |
| KOREA STRAIT | 11° | 4 - 10° |
| STRAIT OF SICILY | 9 - 11° | 0 - 4° |
| JUAN DE FUCA | 9° | 0 - 3° |
| MONTEVIDEO (FEBRUARY) | 13° | 1 - 2° |
| NORWEGIAN SEA | 11 - 12° | 9 - 12° |
| EAST YELLOW SEA | 11° | 0 - 1° |
| KINGS BAY | 15° | 7 - 8° |
| NORTH SEA | 11 - 12° | 0 - 1° |
| SINAI | 11 - 12° | 2 - 3° |

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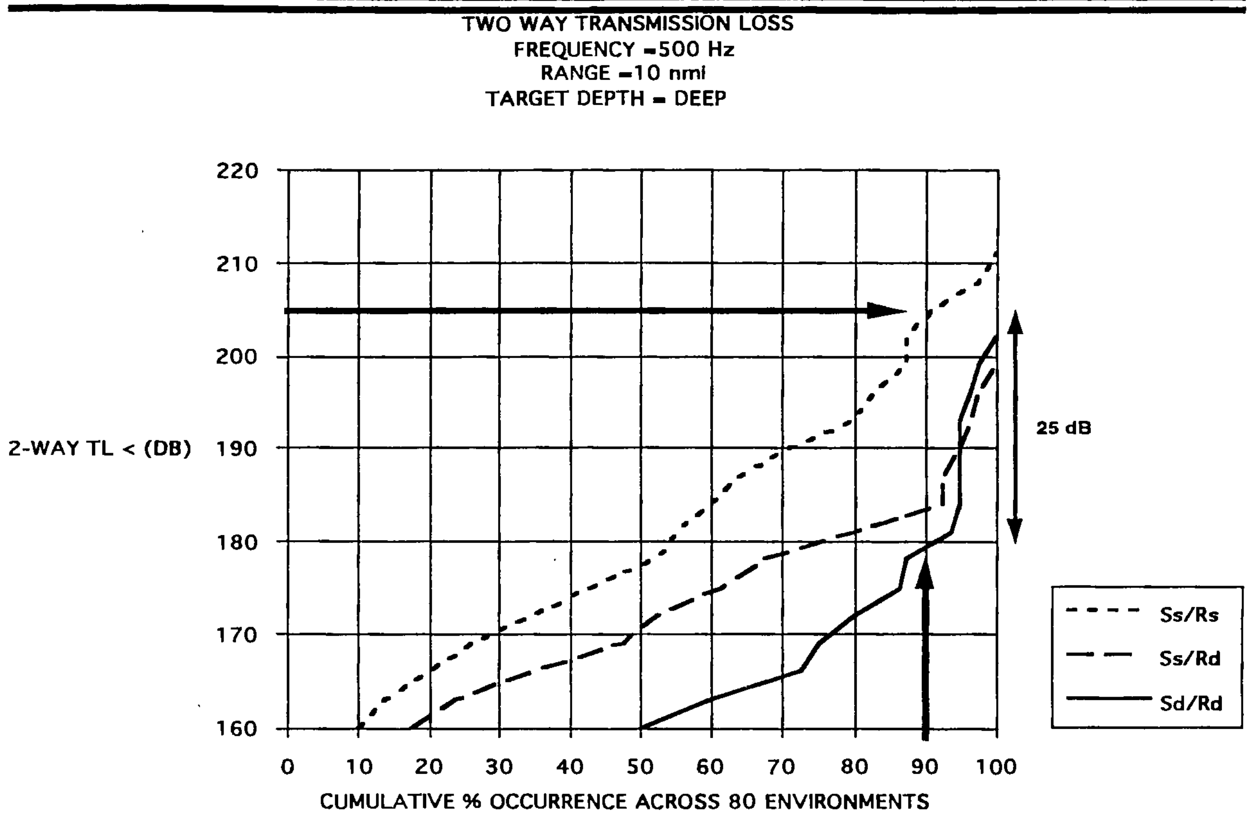


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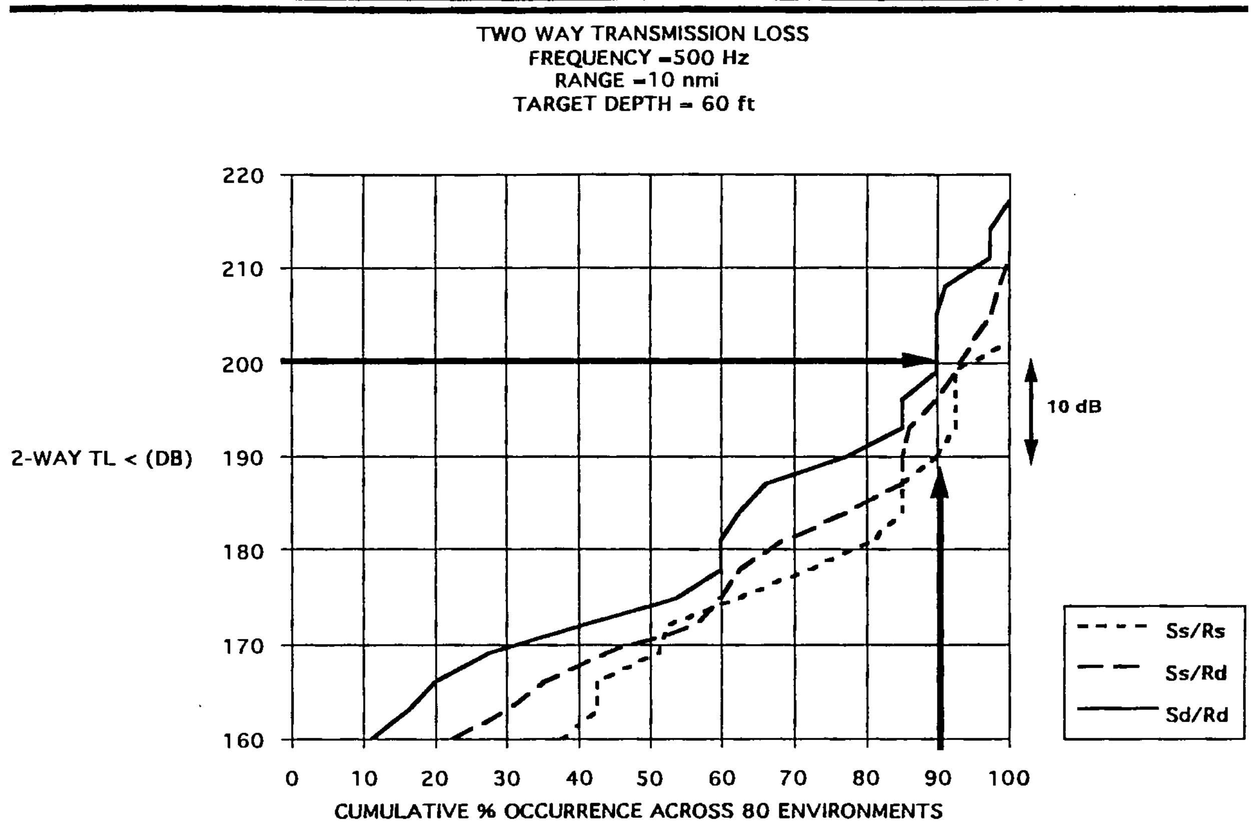


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# CONCLUSIONS

1. IN OUR SURVEY SOME FORM OF DUCTING WAS POSSIBLE FOR MID FREQUENCIES APPROXIMATELY 75% OF THE TIME (10 SITES, 4 SEASONS)
2. WHEN STRONGLY DOWNWARD REFRACTING CONDITIONS EXIST, GRAZING ANGLE DEPENDENCE OF BOTTOM LOSS IS CRITICAL
3. THROUGH KNOWLEDGE OF THE ENVIRONMENT IT IS POSSIBLE TO MINIMIZE PROPAGATION LOSS BY SOURCE/RECEIVER CONFIGURATION IN SHALLOW WATER
4. HISTORICALLY IT HAS BEEN DIFFICULT TO FIND VALIDATED BOTTOM LOSS DATA FOR A GIVEN LOCATION; TO ESTIMATE THE VARIABILITY IN THE REGION; AND DETERMINE THE APPLICABILITY OVER A BROAD FREQUENCY RANGE

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